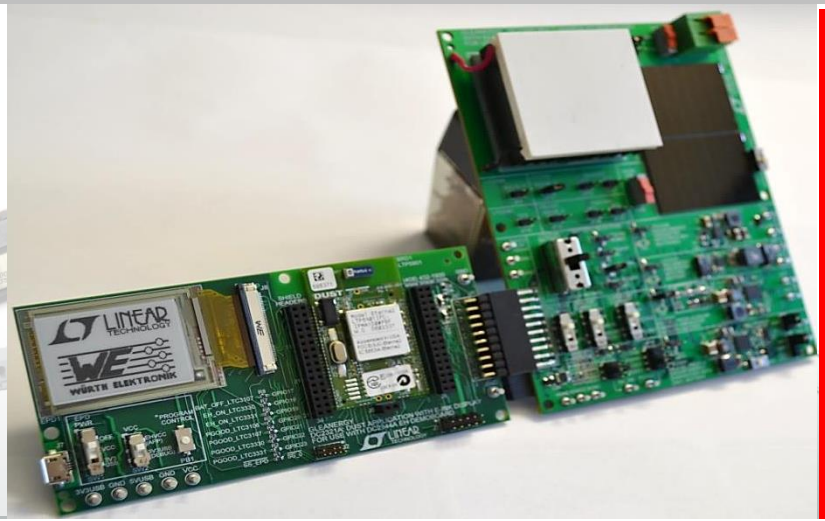
Energy Harvesting is not fiction anymore



Speaker:
Lorandt Fölkel M.Eng
Field Application Engineer &
Business Development Manager
lorandt.foelkel@we-online.de

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LINEAR TECHNOLOGY

NOW PART OF ANALOG DEVICES

Energy Harvesting = Energy for free?

- **Energy harvesting has recently become a topic of much discussion with its potential to self-power autonomous devices for wearables, medical devices and for IoT (the Internet of Things)**

- **Examples of real life use cases demonstrating that Energy Harvesting has already progressed from the laboratory to commercial applications**

- **We need devices that are:**
  - **Wireless (avoid power and communications cables)**
  - **Totally autonomous**
  - **Highly reliable with backup battery lifetime up to 15~20 years**

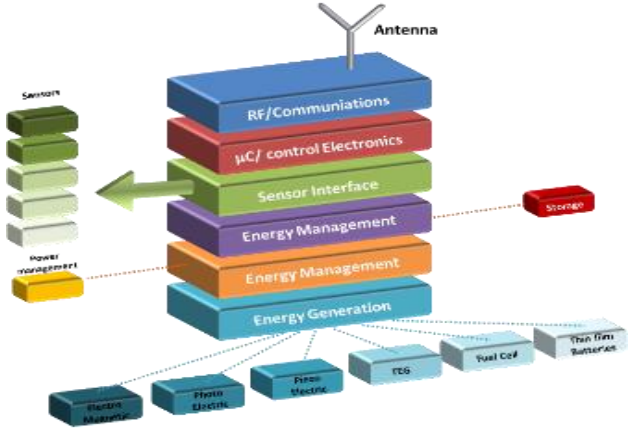
Energy Harvesting = Energy for free?

- We have to consider that the laws of physics are still valid.
- But wasted energy are everywhere
- We just need to :
  - find them
  - convert them (harvest)
  - transform them into electrical energy
  - to store it for the time when not used
  - recall it when needed

Mechanical Age

Source: Linear Technology

Digital Age



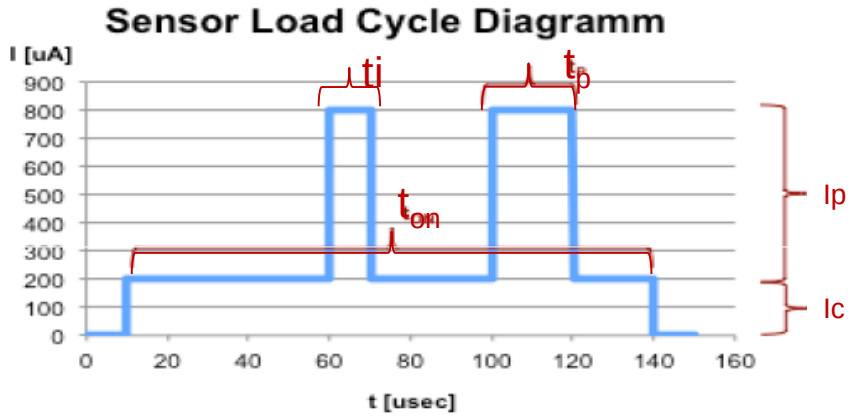
Source: Tyndall National Institute

Wireless IoT devices

Basic consideration for Energy Harvesting

First step:

- calculate the total energy demand for your system
- watch out for your peak energy demand



$$E_{total} = \int V * I * dt$$

$$E_{total} = V_S * (I_c * t_{on} + \sum_i I_{i,p} * t_{i,p})$$

$$P_{AVG} = \frac{E}{\Delta t} = \frac{E_{total} * DC_{AVG}}{\Delta t}$$

Vs: Supply Voltage
Ic: continuous current
Ip: pulsed current

tp,i: pulse duration
ton: system on time
DC: sequence Duty Cycle

Basic consideration for Energy Harvesting

Second step:

- consider the source capabilities
- check multiple source availability (solar, thermo, motion, chemical… etc.)
- watch out for the stability over the time (use a data logger)

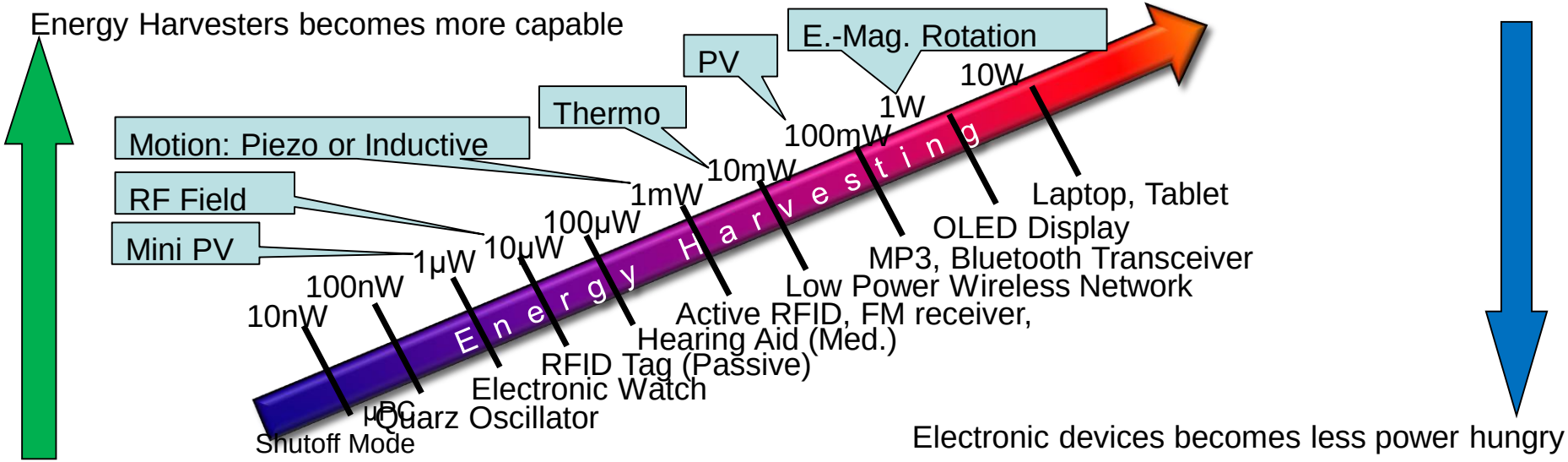
Third step:

- choose the right harvester (transducer)
- build the right voltage converter (source impedance matching)
- consider an energy storage for back up
    - capacity bank
    - supercaps
    - ultracaps (Supercap/Lithium-Ion)
    - Li-Pol rechargeable

Where to find „free energy“

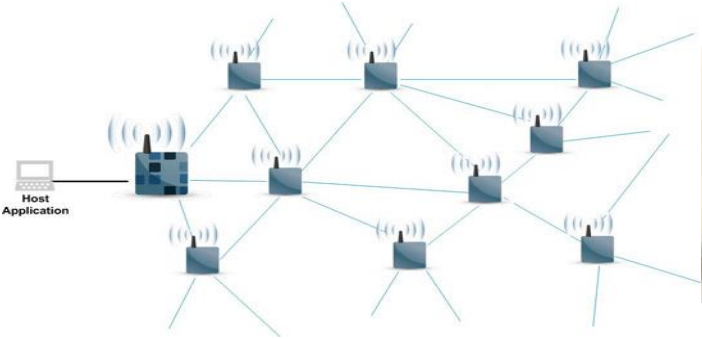
- **Typical energy harvester output power**
  - RF: 0.1µW/cm²
  - Vibration: 1mW/cm²
  - Thermal: 10mW/cm²
  - Photovoltaic: 100mW/cm²

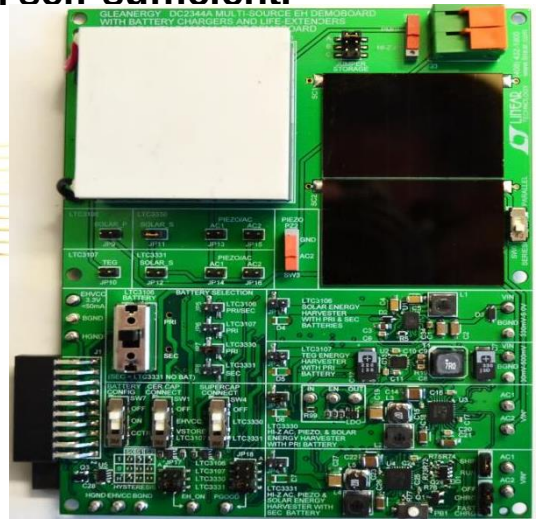
- **Typical energy harvester voltages**
  - RF: 0.01mV
  - Vibration: 0.1 ~ 0.4 V
  - Thermal: 0.02 ~ 1.0 V
  - Photovoltaic: 0.5 ~ 0.7 V typ./cell



Energy Harvesting Kit “Gleanergy” with Battery lifetime extender

- **Environment energy captured and converted into electricity for small autonomous devices making them self-sufficient.**





- Thermo Electric Generator (heat)
- Piezo Electric (vibration/strain)
- Photovoltaic (light)
- Induction (motion)
- Battery (Lithium)

Regulated Voltage
Power Good
EH_ON or Batt. Information

Energy Harvesting Kit – Power Demoboard DC2344A

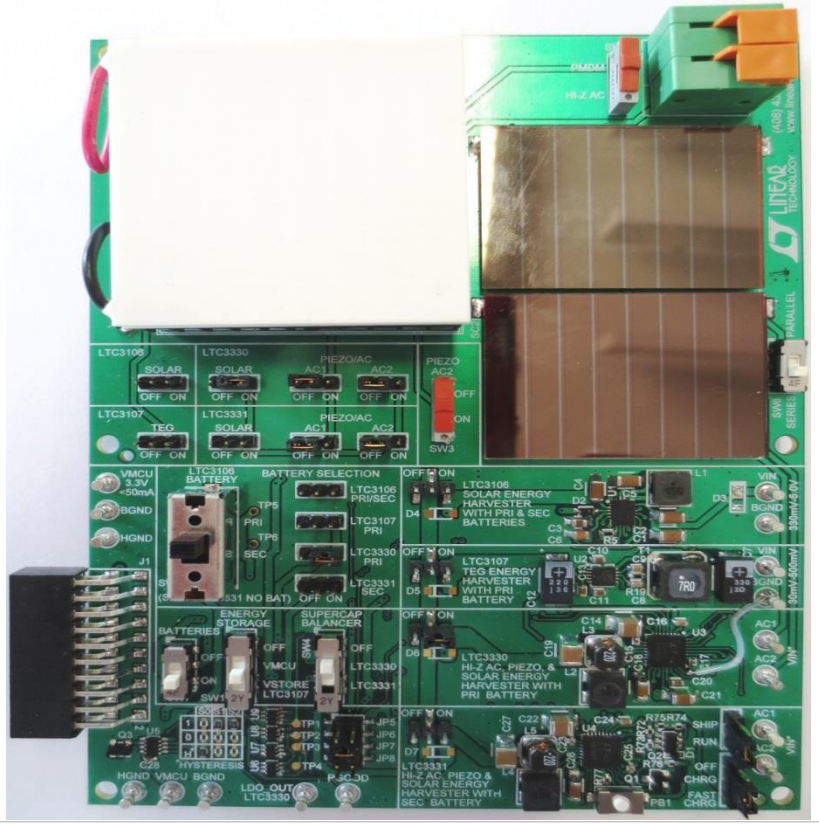
Featuring:

LTC3106 - Solar Harvesting
- Battery Lithium
- Li-Ion Rechargeable

LTC3107 - TEG Harvesting
- Battery Lithium

LTC3330 - Piezo Harvesting
- Solar Harvesting
- Battery Lithium
- Supercap Balancer

LTC3331 - Piezo Harvesting
- Solar Harvesting
- Li-Ion Rechargeable
- Supercap Balancer

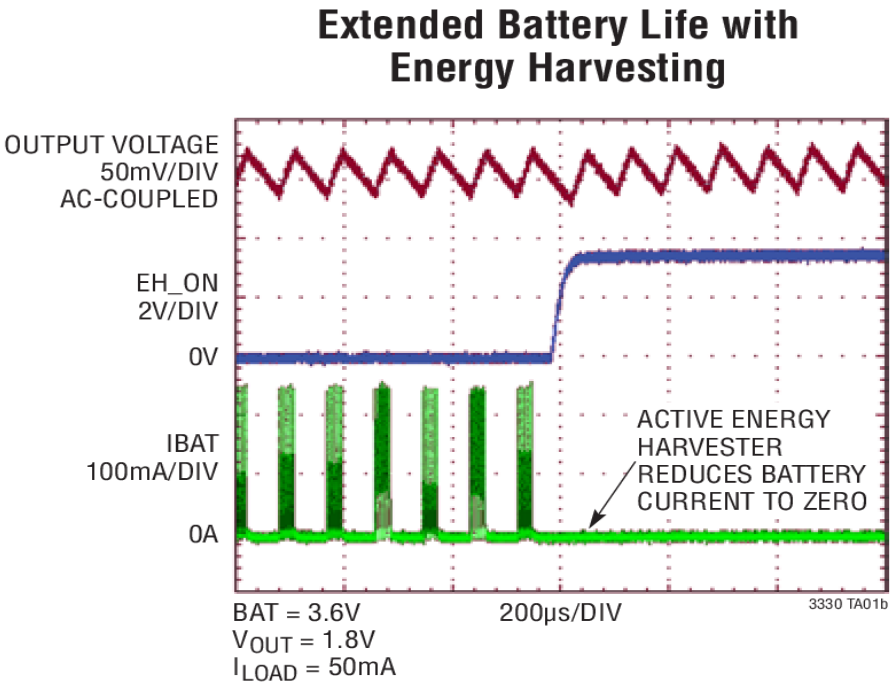


Energy Harvesting Kit – µPC/RF Module Demoboard DC2321A

Featuring:

- TP5901 Dust assembly including ARM Cortex-M3 processor embedded with SmartMesh IP networking software (RF Module)
- E-Ink display for user feedback
- Two coulomb counters for battery data measurement
- Shield board headers and programming headers for development
- Optionally, use **DC2510A** shield board to connect extra components to the ADCs, GPIOs, and serial ports of the mote

LTC3330 Energy Harvesting Solar



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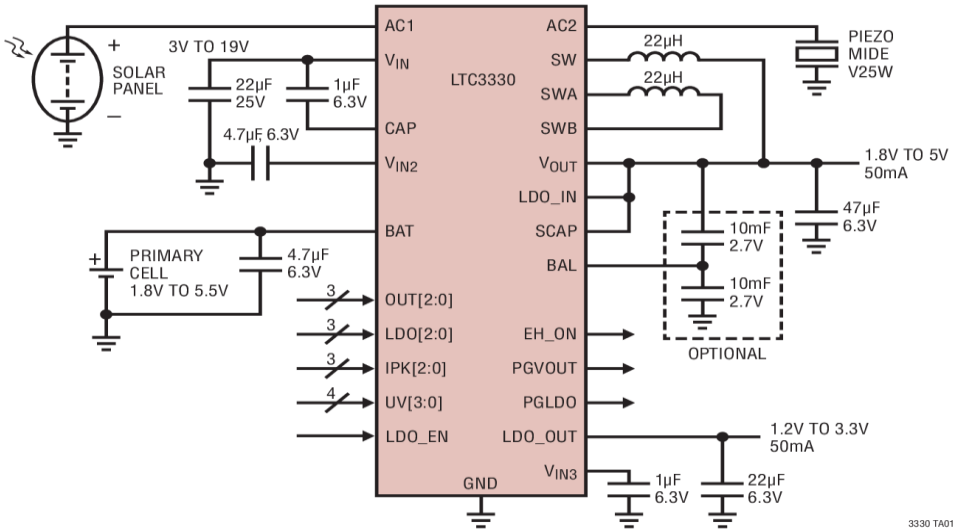


Source: Linear Technology Corporation

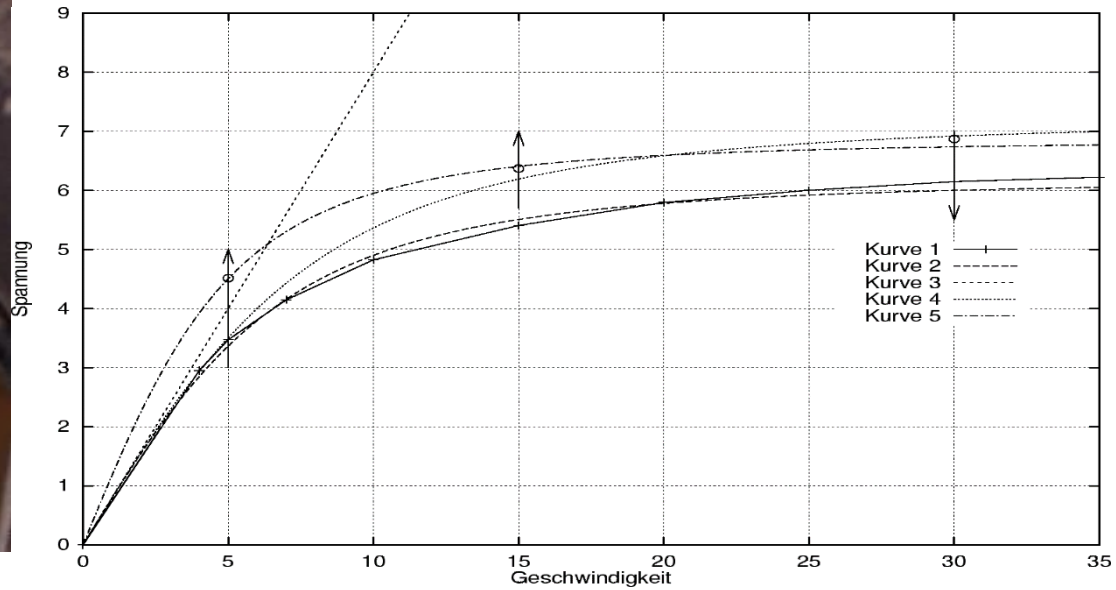
Typical Inductive Transducers

Average Power: 3W

Downhill Peak Power: 4W

Output Voltage: 6V @ 12Ω Load

Felt Efficiency: <10%



Typical Inductive Transducers

EM-1D-09 — Vibration Generator

Generator Data		
Dimensions (L x W x H)	60x24x22	mm
Volume	32	cm^3
Mass	42	g
Inner Resistant	430	Ω
Resonant Frequency	14.2	Hz
Power Output (0.5*g continous*)	3.6	mW
Power Density	0.11	mW/cm^3
Specific Power	85.7	mW/kg
Frequency Range of 50% Power	12.4 - 16	Hz

Generator Code: 151001200019

EM-1D-10 — Vibration and Push-Button Generator

Generator Data		
Dimensions (L x W x H)	60x24x22	mm
Volume	32	cm^3
Mass	46.5	g
Inner Resistant	430	Ω
Resonant Frequency	47	Hz
Power Output (0.5*g continous*)	30	mW
Power Density	0.96	mW/cm^3
Specific Power	660	mW/kg
Frequency Range of 50% Power	42 - 48	Hz
Energy Output (1x Push Button)	1.5	mJ

Generator Code: 151001200018

Source: www.pmdm.de

EnOcean

Per Click 30µC
6.38V @ 4.7µF

Source: www.enocean-alliance.org

Other Development Kits: EnOcean

Source: EnOcean

Product name: EDK 350
Frequency: 868 MHz
Ordering Code: S3004-X350
Description:
The EnOcean Developer Kit EDK 350 gives the designer a fast and full overview of the powerful Dolphin platform. OEMs can develop their own energy-autonomous applications for building automation and other purposes, and assure themselves a competitive edge. The kit covers the entire product range, from energy harvesting and wireless modules to ready-made product solutions

Other Development Kits: ZF Cherry

- **CHERRY's Energy Harvesting Evaluation Kit**

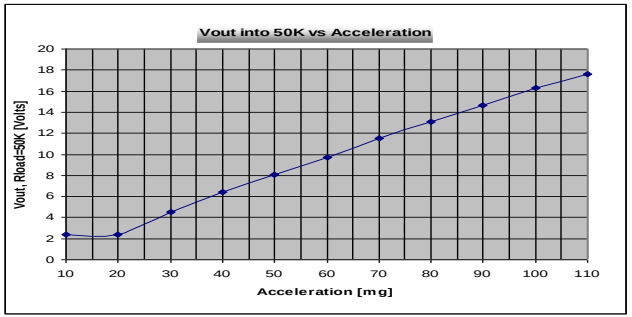
- 1x Energy Harvesting Generator P/N: AFIK-1002
- 1x Wireless Snap Switch
- 1x Wireless Rocker Switch
- 1x Receiver
- 1x USB Cable
- 1x Antenna bushing

Source: ZF Cherry

Typical Inductive Transducers

Ferro Solutions

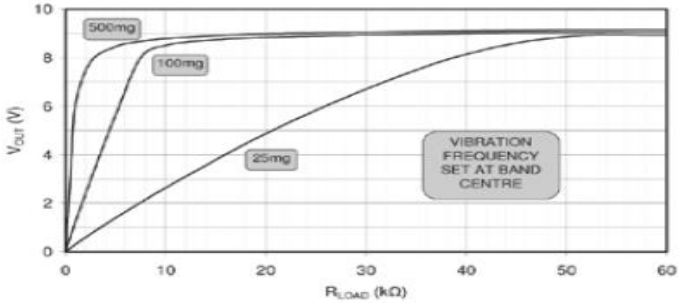
Size: DxH = 6cm x 6.75cm



POWER OUTPUT @ 60 HZ (Rectified DC Power)		
Acceleration	25 milli-*g*	0.3 mW
	50 milli-*g*	1.3 mW
	100 milli-*g*	5.2 mW
BANDWIDTH (Δf = 3 Hz)		
Peak frequency		60 Hz
50% power delivered		+/-1.5 Hz
Q @ 100 milli-*g*		18

Perpetuum

Size: DxH = 6.85cm x 6.85cm



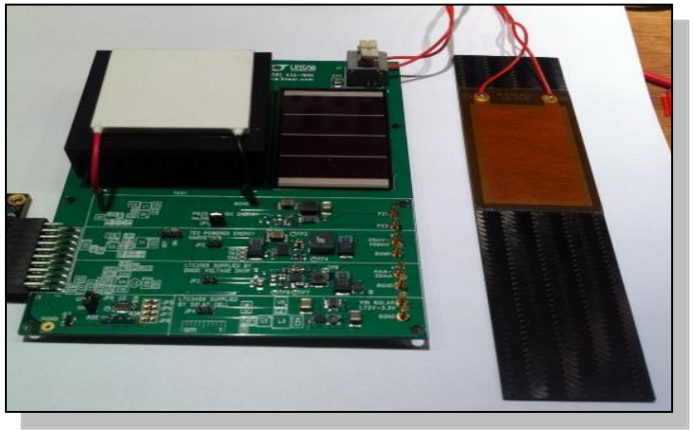
Operates from prevalent 100Hz/ and 120Hz vibration bands found on electrical machines

1mW peak power at 0.025G with >2Hz half-power bandwidth

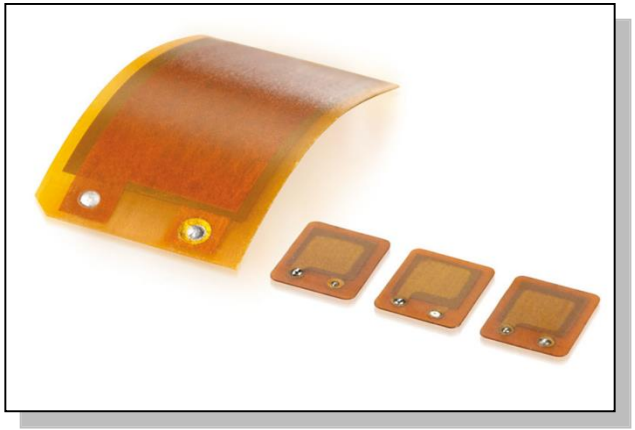
Typically >0.3mW output on 95% of machines

Examples for Piezo Transducers

PI Ceramic



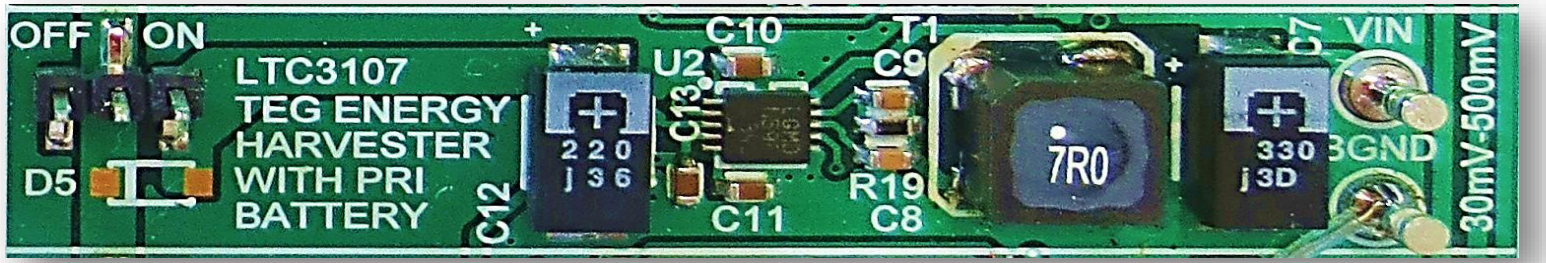
The “Piezo Ruler” Size: 150 x 35 x 2,5 mm³

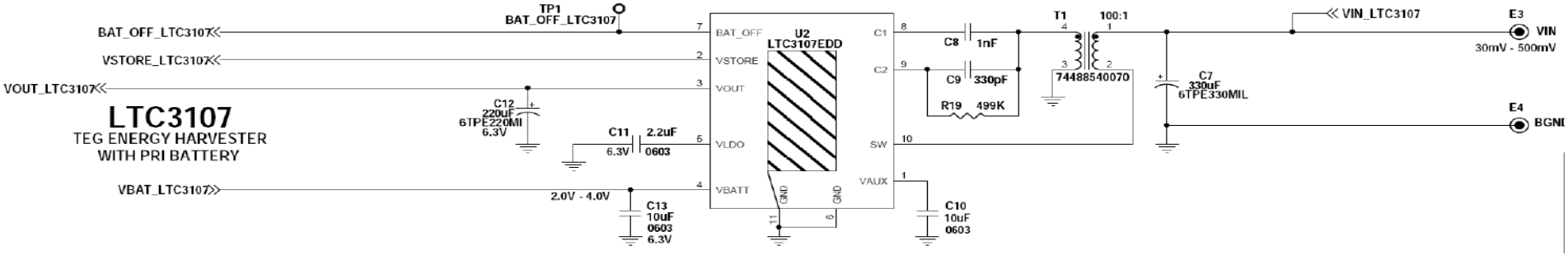


Made from DuraAct Transducers

Source: Linear Technology Corporation

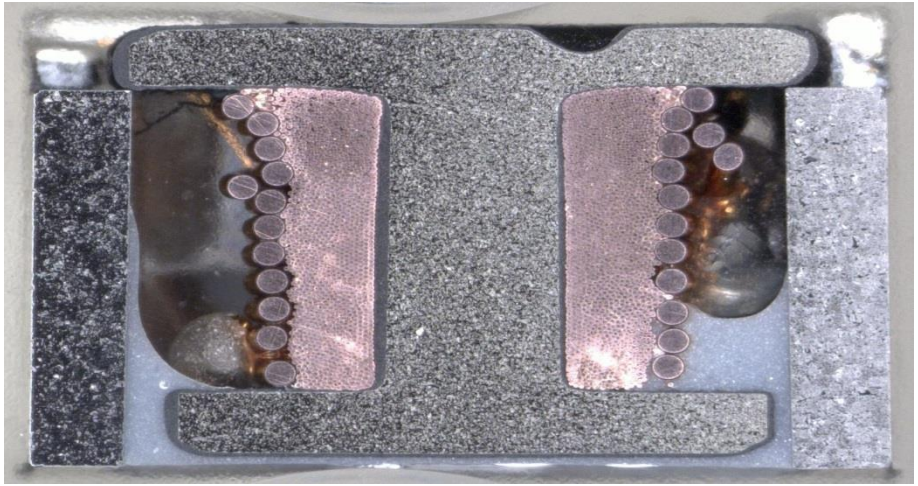
EH-Kit: LTC3107 - TEG

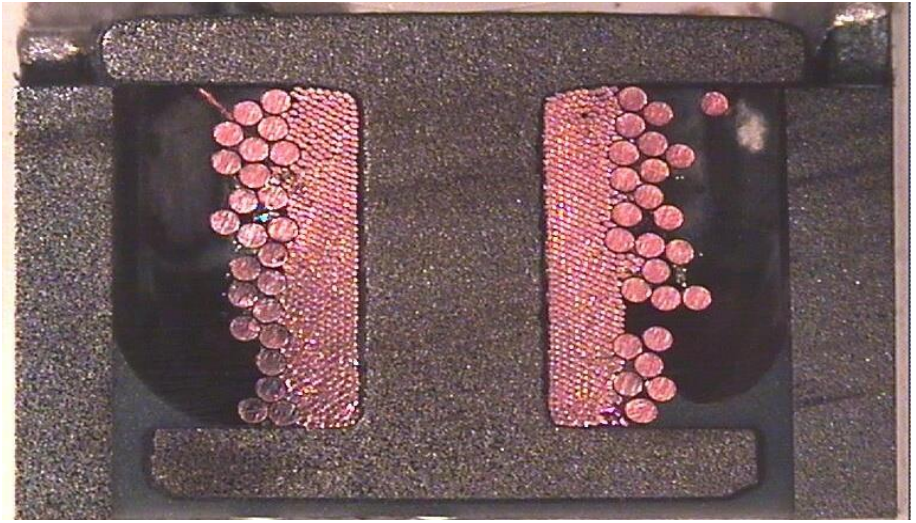




What is behind the WE-EHPI transformer?

- **winding style**





Würth Elektronik eiSos components WE-EHPI

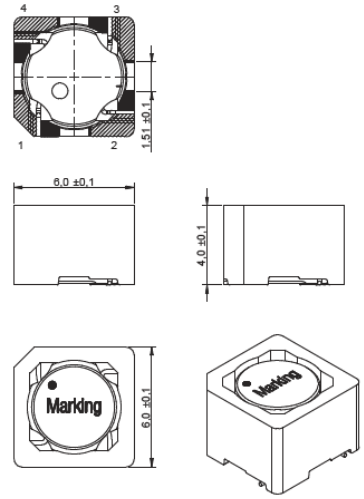
Characteristics:

- Low profile: 4 mm
- Small footprint 6 x 6 mm
- Very low secondary R_{DC}
- Multiple options of turn ratios available
- Separated welding/soldering pads for increased reliability
- Optimized winding technology for increased performance & reliability

Applications:

- Wireless fire, alarm, gas and metering remote sensors driven by environmental energies based on energy harvesting voltage transformers like LTC3108/LTC3109
- Sensors with predictive battery replacements in applications which are difficult to access
- Energy self-sufficient supply using subsequent installed sensors for energy harvesting

Dimensions: [mm]



Electrical Properties:

Order Code	L_1 (µH)	Tol. L_1	L_2 (µH)	Tol. L_2	n	I_R (A)	I_{SAT} (A)	$R_{DC1\ typ.}$ (Ω)	$R_{DC1\ max.}$ (Ω)	$R_{DC2\ typ.}$ (Ω)	$R_{DC2\ max.}$ (Ω)
74488540070	7	±20%	70000	±20%	1 : 100	1.9	1.3	0.085	0.095	205	240
74488540120	13		33000		1 : 50	1.7	1	0.09	0.1	135	155
74488540250	25		10000		1 : 20	1.5	0.7	0.2	0.24	42	48

I_R: Rated Current ; I_{SAT}: Saturation Current ; L_1: Inductance 1; L_2: Inductance 2; n: Turns Ratio; $R_{DC1\ max.}$: DC Resistance 1; $R_{DC1\ typ.}$: DC Resistance 1; $R_{DC2\ max.}$: DC Resistance 2; $R_{DC2\ typ.}$: DC Resistance 2; Tol. L_1: Inductance 1 (Tol.); Tol. L_2: Inductance 2 (Tol.)

Transformer designed on EP7 cores are available on request – Order code: 760370096, 760370097, 760370098
During design stage of this series, we used S11100032, S11100033 & S11100034.
With our standard series we have replaced these order codes.

Where is it useful?

- Where line power is unavailable or costly
- Where batteries are costly or difficult to replace
- Where energy is needed only when ambient energy is present

Asset Tracking/Monitoring

Building Security, Lighting & Climate Control

Plant Automation

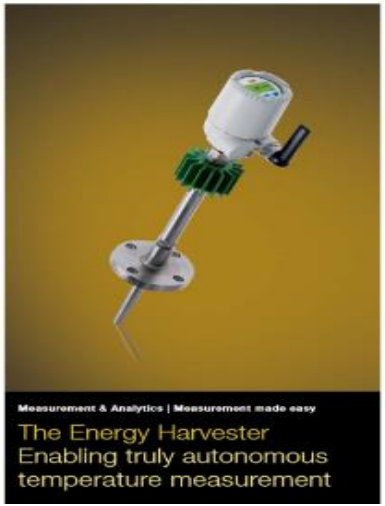
Remote Monitoring

TPMS

Source: LTC - Sam Nork – Energy Harvesting Presentation

Industrial Application

- TSP300-W with Energy Harvester – the first autonomous Wireless temperature sensor.
- Enables the easy addition of temperature measuring points throughout operations.
- Shorten installation times by eliminating complex wired infrastructure and lower overall implementation costs of process measu wireless devices



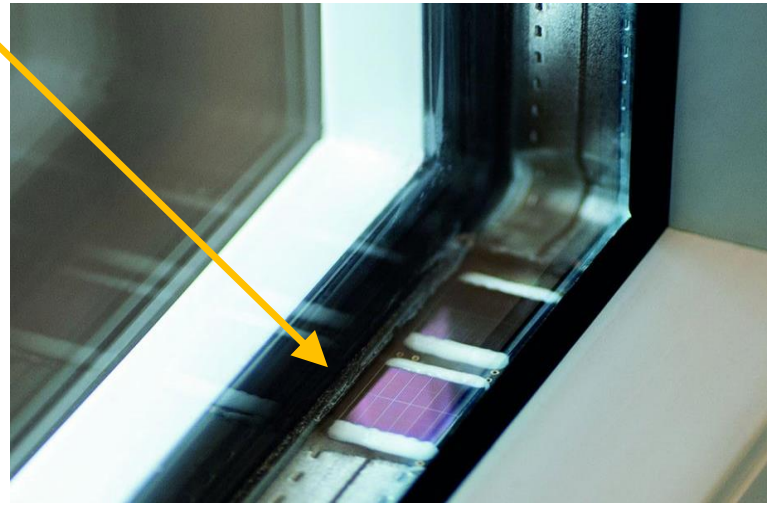
Source: ABB

Energy Harvested Application

- Customer feedback for EH projects:
  - Total amount of harvested energy: min 50µW up to 200mW
  - The highest harvested energy was 5W using Solar cells

Devices are:

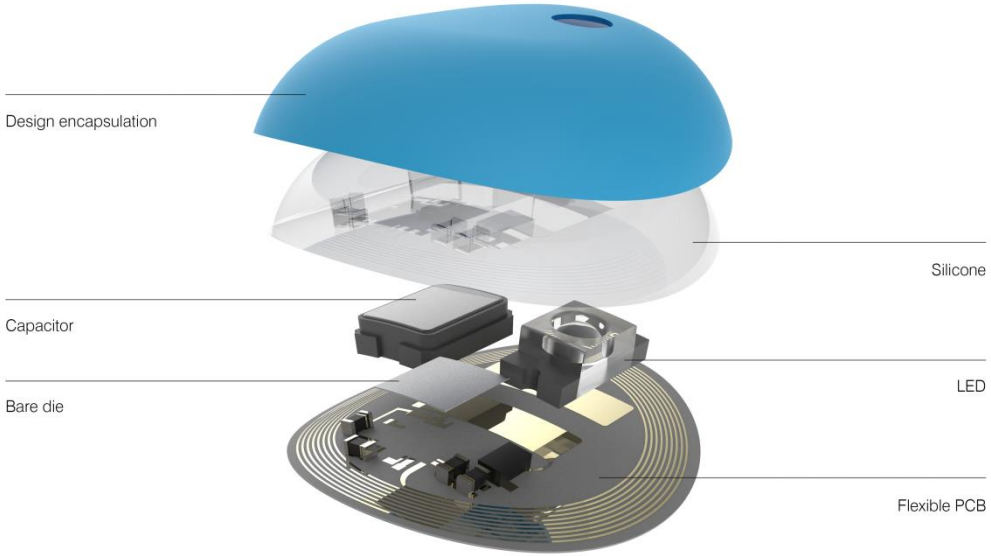
- Aftermarket solutions for Portable Navigators & Mobile Phones (Solar)
- GSM/GPS module (5W Solar)
- Window status monitoring for Hotels and Homes (Solar)
- Chainsaw electronic at engine (TEG)
- High Voltage cable status (Magnetic field)
- Water purification plant PH measuring (chemical)
- Temperature measurement for engines (TEG)
- Object tracking at airport (Piezo & RF-ID)



Source:© Fraunhofer IMS

L‘Oreal UV sensor

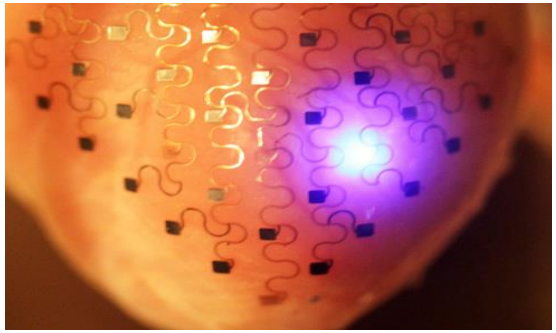
The device is battery-free electronic UV sensor and it’s small enough to wear on one of your nails. Using NFC, the device can connect to your phone and deliver log data on sun exposure.

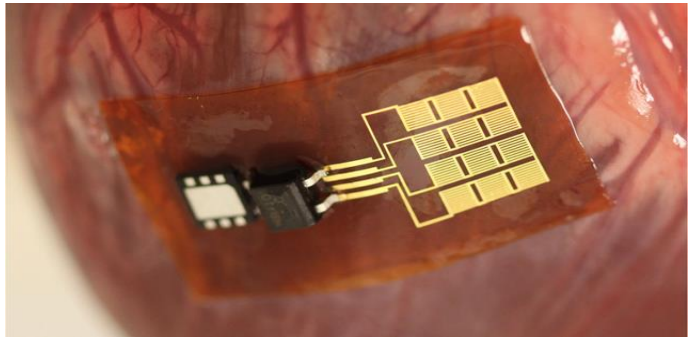


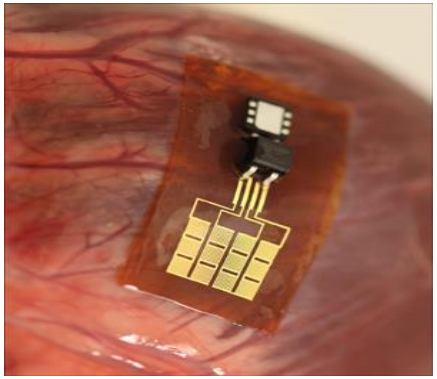
Source: L‘Oreal at dezeen.com

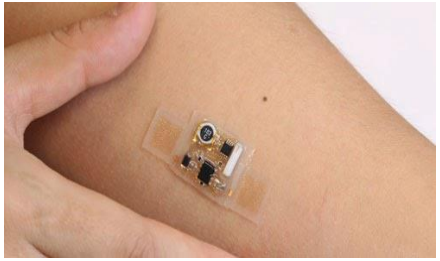
Energy Harvesting Healthcare Application

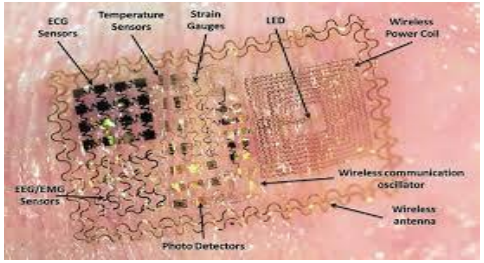
- **Pacemaker**

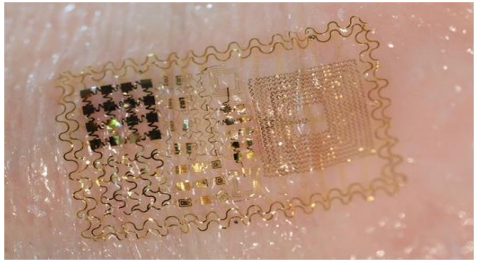


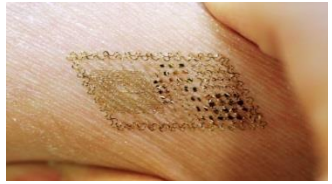












Source: Prof John A. Rogers University of Illinois

Another application for Harvesting?

Source: http://www.joaolammoglia.com/concept/1/aire-concept/

Energy Harvesting Evaluation Boards:
“Gleanergy” p/n: IC-744 888
“To Go” Kit p/n: IC-744 885

More information at our booth:

www.we-online.com/gleanergy

In collaboration with:

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